The International Atmospheric Circulation Reconstructions over the Earth (ACRE) initiative

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Abstract

Between the millennial scope of paleoclimate reconstructions and the centennial outlook of climate model projections stands the instrumental record of global climate variability and change. Recovering, understanding, and utilizing this record over the last 200-250 years are the goals of the international Atmospheric Circulation Reconstructions over the Earth (ACRE) initiative. ACRE is investigating worldwide climate variability and change over the past 200-250 years. It accomplishes this by facilitating and linking projects that are recovering historical weather observations, performing long reanalyses and using these in global, regional, and local climate variability and climatic change applications.

Capsule

ACRE both undertakes and facilitates the recovery of instrumental terrestrial and marine global surface weather observations to underpin global climate reanalyses spanning the last 200-250 years for the full range of international user needs.

Introduction

The international Atmospheric Circulation Reconstructions over the Earth (ACRE) initiative (http://www.met-acre.org/) is led by five core partners - the Queensland Climate Change Centre of Excellence (QCCCE) in Australia; the Met Office Hadley Centre (MOHC) in the UK; the US National Oceanic and Atmospheric Administration (NOAA) Earth System Research Laboratory (ESRL) and the Cooperative Institute for Research in Environmental Sciences (CIRES) at the University of Colorado at Boulder; and the universities of Giessen in Germany and Bern in Switzerland. This core team provides an umbrella that links more than 35 projects, institutions and organisations, around the globe (Figure 1). In 2010, ACRE and its activities were ratified by the WMO Commission for Climatology, extolled in the Implementation Plan for the Global Observing System for Climate in Support of the UNFCCC (2010 Update), and endorsed by the Joint WMO-IOC Technical Commission on Oceanography and Marine Meteorology Expert Team on Marine Climatology and by the World Climate Research Programme.

ACRE's activities fall into three main groups: recovering historical observations, global climate reconstruction through reanalysis, and facilitating the use of these reconstructions.

Recovery, imaging and digitisation of historical global surface weather observations

ACRE works closely with the international surface weather and climate observations community: particularly the International Surface Pressure Databank (ISPD, http://dss.ucar.edu/datasets/ds132.0/), the International Comprehensive Ocean-Atmosphere Data Set (ICOADS, http://icoads.noaa.gov), the international RECLAIM (RECovery of Logbooks And International Marine data, http://icoads.noaa.gov/reclaim/) and the International Environmental Data Rescue Organisation (IEDRO, http://www.iedro.org/) projects, and NOAA's National Climatic Data Centre (NCDC) Climate Database Modernization Program (CDMP, Dupigny-Giroux et al. 2007) in the US. These programs, together with various international academics and archives, are working to expand the recovery, imaging, and digitisation of historical instrumental weather observations.

Major current activities at the MOHC focus on data held in various UK repositories (e.g. The British Library [BL], the National Meteorological Archive [NMA] and The National Archives [TNA]) plus establishing regional efforts in Chile, India and the India Ocean, the Pacific, southern Africa and China.

The range and extent of various specific historical weather data recovery, imaging and digitisation projects that ACRE has undertaken over the last three years cover 'industrial scale' activities, such as imaging and digitisation of 900 logbooks from ships of the English East India Company (EEIC) (1780s-1830s) sailing the North and South Atlantic Oceans, the Indian Ocean and South China Sea (imaged by the BL and digitised by CDMP) and some 3,000 Royal Navy

logbooks (imaged by the TNA and digitised under OldWeather.org) from the extended period during and following World War 1 (1914-1923). Specific projects have also been linked under ACRE, such as CoRRaL: UK Colonial registers and Royal Naval Logbooks (www.corral.org.uk) – logbooks of ships on voyages of discovery or attached to the UK Hydrographic Office (UKHO) (1700-1850: held in TNA), plus UK colonial meteorological registers, journals and gazettes (held at TNA and the NMA).

Smaller-scale digitisation is also an ongoing ACRE activity, and is addressing material from various secondary sources such as published books, journals, ship logbooks and reports of marine and terrestrial weather data from expeditions, travels, circumnavigations and ships of exploration. This material was especially valuable in providing observations for polar regions for the 20th Century Reanalysis Project (20CR) 1871-2008 and Brohan *et al.* (2010). Other efforts include inventories of data holdings, such as UK hydrographic and survey vessel remarks books, 6,000 of which of which exist at the UKHO (from 1759 to 1909) and have never been digitised, and the Chinese and South China Sea weather observations of The Chinese Maritime Customs, which ACRE employed Bristol University (http://www.bristol.ac.uk/history/customs/) to inventory. This material contains historical instrumental meteorological observations made at Chinese inland stations, and by ships travelling along its rivers, coastline and in the South China Sea.

Finally, there are ACRE regional activities and linked projects, as seen in Figure 1, such as ACRE Chile which aims to digitise 19th and 20th century weather observations in Chilean archives. ACRE Chile is now part of the ECMWF-led FP7 proposal ERA-CLIM through The Direccion Meteorologica de Chile, Centro para el Cambio Global, Universidad Católica de Chile and the University of Chile (Department of Geophysics) in Santiago, and the South Eastern Australian Recent Climate History project (SEARCH - http://climatehistory.com.au/), which is assembling pre-20th century data suitable for temperature, rainfall and atmospheric pressure reconstructions over south-eastern Australia (Gergis *et al.,* 2009, 2010).

Figure 2 shows a schematic representation of how the various historical marine and terrestrial weather observations recovered and digitised under the above ACRE activities and projects flows through the international surface weather observational framework and infrastructure and into the international repositories for such data.

ACRE-facilitated reanalyses

For most users of long-term climate reconstructions the raw observations, with their limited and variable spatial coverage, are difficult to use. Much value can be added to the raw observations by assimilating them into a global, gridded, reconstruction of the weather. Many weather observations recovered by ACRE and its partners have already

enhanced the ISPD and been assimilated into the 20th Century Reanalysis dataset (20CR, 1871-present) (http://www.esrl.noaa.gov/psd/data/20thC_Rean/, (Compo *et al.,* 2010).

At a recent technical workshop on reanalysis hosted by NASA's Global Modelling and Assimilation Office (GMAO), ACRE's data activities were expanded to cover the needs of all reanalyses, such as the upcoming reanalyses by the Japan Meteorological Agency (JMA-55) and European Center for Medium range Weather Forecasting (ECMWF) (ERA-CLIM) as well as the National Centers for Environmental Prediction's next effort back to the 1950's. This has been further strengthened by the involvement of ACRE in two new European Commission (EC) Seventh Framework Programme Co-operation (FP7) projects, the Royal Netherlands Meteorological Institute (KNMI)-led EURO4M, European Reanalysis and Observations for Monitoring, and ECMWF-led ERA-CLIM, European Reanalysis of Global Climate Observations. Additional reanalyses are also envisioned by ACRE's partners at NOAA/ESRL and the University of Colorado, covering even longer periods: a Surface Input Reanalysis for Climate Applications (SIRCA) (1850-2014) and eventually extending back to 1800.

The impact that ACRE's data activities will ultimately have on the amount of global historical surface weather observations available for the 20CR, future ACRE-facilitated reanalyses and international reanalyses in general can be seen in Figure 3.

Users of ACRE-facilitated Data and Reanalyses

These reanalyses will produce reconstructions of global historical weather conditions which can serve the full range of users – from climate researchers, the diverse climate applications community, to educators, students and the general public. To make the reconstructions as user friendly, tailored, widely available and interactive as is possible, the initiative is embracing the development of technologies in the areas of citizen science digitisation, massive scale data handling and web-based, state-of-the-art, high resolution visualisations.

The first ACRE-facilitated reanalysis product, global four-times-daily atmospheric and surface analysis fields spanning 1871 to 2008 from the 20CR Version 2 dataset are available at (http://www.esrl.noaa.gov/psd/data/gridded/data.20thC_ReanV2.html) in netCDF format, courtesy of NOAA ESRL's Physical Sciences Division, and the University of Colorado CIRES Climate Diagnostics Center. 20CR fields are also available for the complete period in GRIB format courtesy of the US National Center for Atmospheric Research (http://dss.ucar.edu/datasets/ds131.1). They will also available via NOAA's National Climatic Data Center (NCDC) through the NOAA Operational Model Archive and Distribution System (NOMADS) Data Archive

(http://nomads.ncdc.noaa.gov). Plotting tools for subdaily, daily-averaged and monthly mean fields are now available at (http://www.esrl.noaa.gov/psd/data/composites/day_20thc/).

As user interaction and engagement is a fundamental component of ACRE, strenuous efforts have been made to work with climate researchers, the diverse climate applications community, educators, students and the general public. In addition, ACRE is engaging with wider cross and interdisciplinary initiatives such as the international student GLOBE Program and its Student Climate Research Campaign (SCRC) for 2011-2013 (http://www.globe.gov/content/scrc) and the OldWeather.org and Data.Rescue@Home citizen science projects (http://www.oldweather.org/ and http://bjerknes.ethz.ch/tx/drah/). The latter are using citizen science pilot projects to showcase the potential of mass weather data digitisation via citizen science. It is hoped that this will help to engage the wider public at a time when climate and climate change research findings are being questioned. In fact, in the wake of the so-called 'climate gate' incident, land surface temperatures dynamically reconstructed by the ACRE-facilitated historical weather reanalyses will be used to provide an independent data base with which to check and access the observed historical surface temperature record.

The range of projects and studies that are known to be using the ACRE-facilitated data and reanalyses, are employing this material to reassess global climate phenomena, such as historical tropical and midlatitude cyclone activity and storminess, ENSO events and dynamics, drought episodes, Arctic warming, the South Pacific Convergence Zone (SPCZ), regional rainfall drivers, marine zoology and oceanography, and evaluations of a new global surface air temperature data base following 'Climate Gate'.

As the ACRE-facilitated data and reanalyses products and their user potential become more widely known, their value will increase. Early projects looking to use the ACRE-facilitated data and reanalyses products are addressing extremes (such as storms, etc.), climate modes and reanalysis-based approaches to agricultural resilience, and the wider applications that would come from their use with new high resolution reanalyses for Europe EURO4M and potentially longer ERA-75 global reanalysis ERA-CLIM projects and products

The historical record of climate variability, and the document archives on which it is based, are of interest outside the weather and climate community; and the ACRE has embraced the cross/interdisciplinary interest its activities have created. A series of recent collaborations between ACRE and citizen science, social science and humanities partners, have made the above interactions an essential component of the initiative. Such projects are the OldWeather.org and Data.Rescue@Home citizen science projects, the Sailsproject (Shipping Archives and Integrated Logbooks of Ships:

http://sailsproject.cerch.kcl.ac.uk/) and, with the Centre for e-Research, King's College London, looking at historic sources for weather in order to develop e-Research approaches to modelling, visualising and analysing such data. The latter network will build partnerships between scientists and humanities researchers around historic source materials that relate to weather, including ship's logs.

Conclusion

ACRE has shown what can be done to develop and fuse together global data, reanalyses, and user interactions, activities and engagements. This overview highlights the scope of the initiative, and its ongoing capacity to both evolve and initiate coherent linkages between national and international projects, organizations and institutions. Thus, ACRE is implementing major elements of the global strategic plans and calls of the international scientific community, and generates outputs and outreach which satisfy and engage users worldwide.

In undertaking the above, ACRE has developed a viable international data recovery, imaging and digitization program that combines a mixture of activities covering the full spectrum from small 'cottage' to extensive 'industrial' scale projects. This work has also provided engagement with researchers and institutions in the social sciences and humanities, by capturing a mass of contextual material that such disciplines need but can rarely access in such quantities.

ACRE is a response to user needs, and through its core linkages between observations, reanalyses and the tailoring, shaping and downscaling of that material in alignment with user requirements, the initiative is filling a vital role in making climate science products freely available and their generation transparent to all users. Through its efforts to develop state-of-the-art visualization technology, ACRE is building the infrastructure to deliver the initiative's output and outreach globally. In any of its components, ACRE welcomes further engagement with the international community.

Acknowledgements

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sMarshall, Ø. Nordli, M.A. Valente, R.M. Trigo, I. Auer, D. Wheeler, C. Wilkinson, C. Ward, S. Jourdain, A. Klein-Tank, S. Brönnimann, D. Dee, S. Uppala, X. Wang, R. Przyblak, K.R. Wood, J. Overland, M. Maugeri, M. Brunetti, D. Jones, P. Arkin, K. Casey, J. Carton, A.S. Cofiño, J.W. Buchanan, M. Haylock, P. Della-Marta, R. Bickers, C. Reason, E. Hanna, H. Meinke, C. Marzin, J. G. Guzman-Gutierrez, J. Gergis, E. Parsons, P. Woodworth, R. Solberg, A. Lorrey, A. Tasker, E. Geary, S.J. Worley, M. Küettel, C. Lintott, L. Hughes, P. Aceituno, S. Sensoy, G. Hughes.

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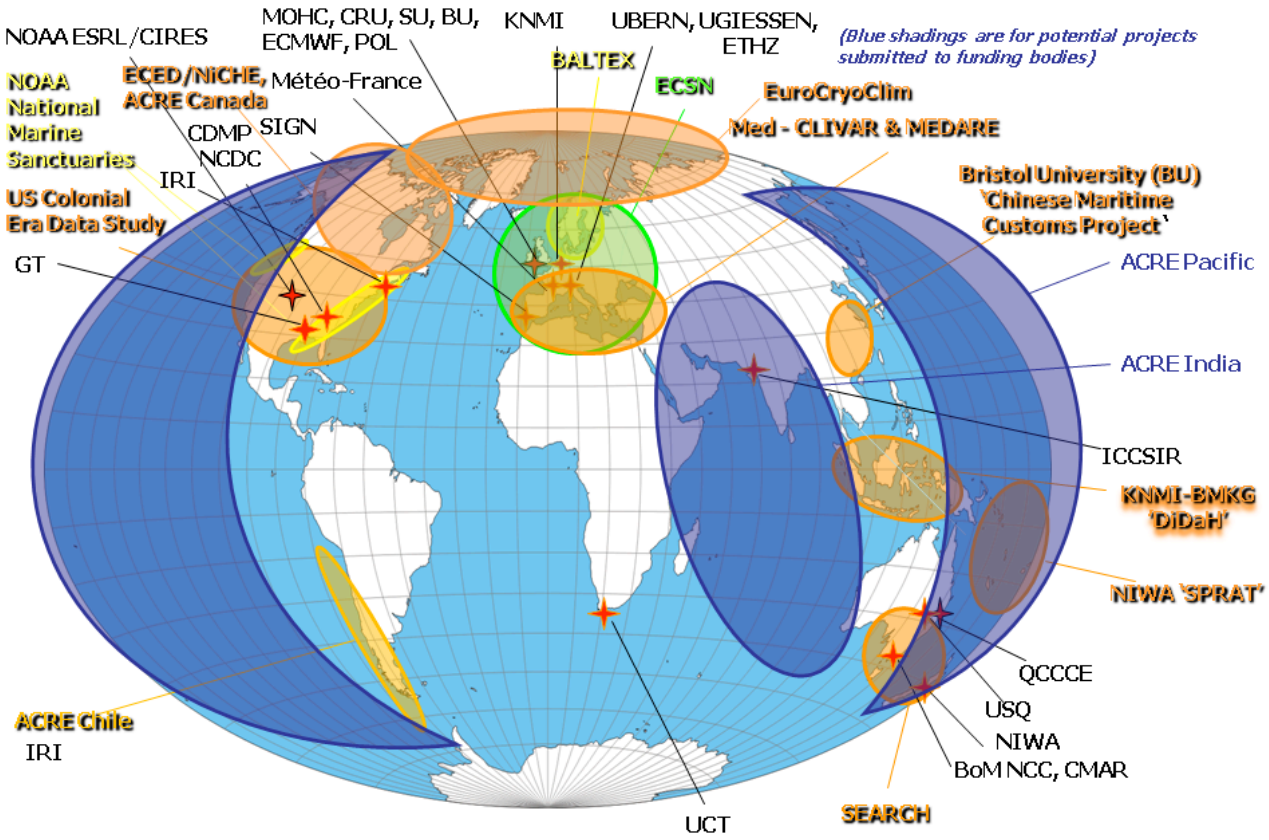
Figure 1: The full global range of collaborations, linkages and projects involved in ACRE to date. Acronyms not defined in the text in Figure 1 and 2 are defined and detailed at http://sites.google.com/a/met-acre.org/acre/links.

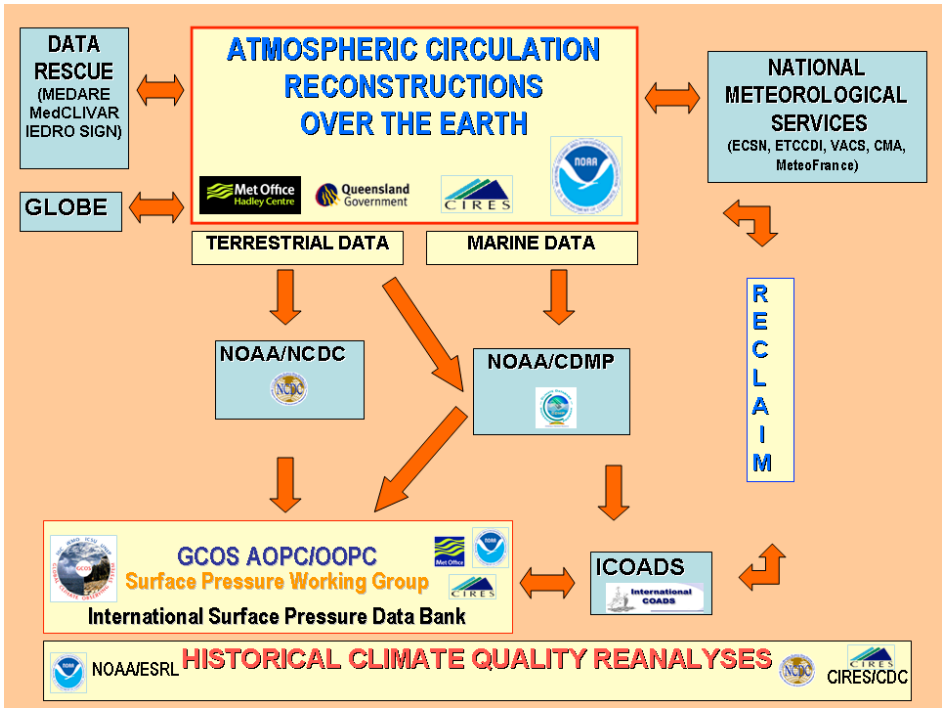
Figure 2: ACRE data flow within the international surface terrestrial and marine infrastructure.

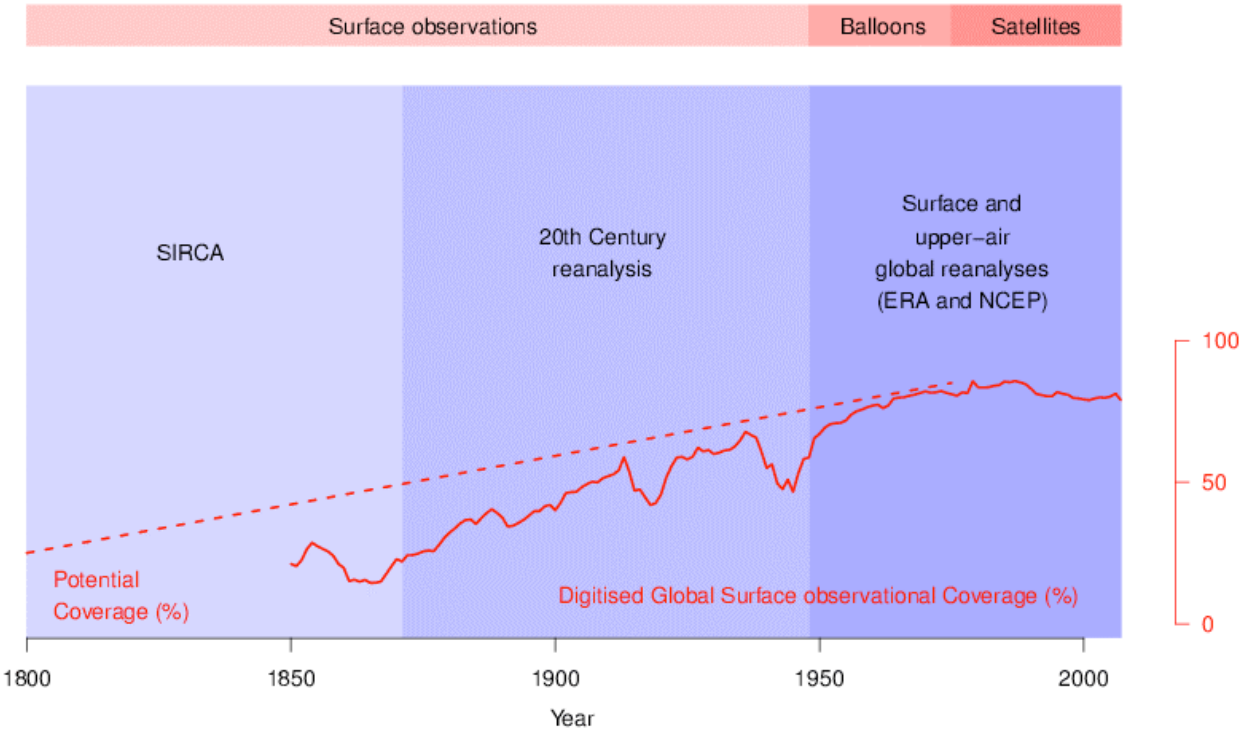
Figure 3: Potential impact of ACRE data activities on surface observations available for historical reanalyses. Solid red line is a schematic of the percentage of global surface observations that have been digitized, the dashed red line shows the potential improvement in global surface observations digitized as a result of ACRE. The blocks shaded blue through time show the range of ACRE-facilitated historical weather reanalyses in the context of contemporary international NCEP and ECMWF reanalyses.



International Projects, Sources & Repositories linked to ACRE

IEDRO ICOADS ISPD WMO DARE RECLAIM GLOBE GLOSS ETCCDI VACS ICHM Galaxy Zoo
CoRRaL EU FP7: EURO4M EU FP7: ERA-CLIM NERC: AUSTRAL Reanalysis.org


DATA RESCUE
(MEDARE
MedCLIVAR
IEDRO SIGN)
GLOBE
ATMOSPHERIC CIRCULATION RECONSTRUCTIONS OVER THE EARTH
Met Office Hadley Centre
Queensland Government
CIRES
TERRESTRIAL DATA
MARINE DATA
NATIONAL METEOROLOGICAL SERVICES
(ECSN, ETCCDI, VACS, CMA, MeteoFrance)
RECLAIM
NOAA/NCDC
NOAA/CDMP
GCOS AOPC/OOPC
Surface Pressure Working Group
International Surface Pressure Data Bank
ICOADS
International COADS
NOAA/ESRL
HISTORICAL CLIMATE QUALITY REANALYSES
CIRES/CDC


Surface observations
Balloons
Satellites
SIRCA
20th Century reanalysis
Surface and upper–air global reanalyses (ERA and NCEP)
Potential Coverage (%)
Digitised Global Surface observational Coverage (%)
100
50
0
1800
1850
1900
1950
2000
Year